A Comparison of Hypertext and Boolean Access to Biomedical Information

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This study explored which of two modes of access to a biomedical database better supported problem solving in bacteriology. Boolean access, which allowed subjects to frame their queries as combinations of keywords, was compared to hypertext access, which allowed subjects to navigate from one database node to another. The accessible biomedical data were identical across systems. Data were collected from 42 first year medical students, each randomized to the Boolean or hypertext system, before and after their bacteriology course. Subjects worked eight clinical case problems, first using only their personal knowledge and, subsequently, with aid from the database. Database retrievals enabled students to answer questions they could not answer based on personal knowledge only. This effect was greater when personal knowledge of bacteriology was lower. The results also suggest that hypertext was superior to Boolean access in helping subjects identify possible infectious agents in these clinical case problems.

INTRODUCTION

The availability of online biomedical information and knowledge resources challenges us to reconceptualize the processes of health care and education in the clinical and basic biomedical sciences. The clinician/learner is now potentially empowered by these resources as never before. Barnett has spoken to the potential of "just in time" education, bringing to the clinician/learner exactly the information s/he needs to address a problem at exactly the time it is most needed.[1] When these systems become fully operational, it will be possible to conceive of the problem solver not as the individual alone but as the individual tightly linked to an array of information resources, as originally envisioned by Vannevar Bush in his classic paper, "As we may think." [2]

The power and appeal of this vision notwithstanding, many technical and empirical issues remain before it is achieved. One such issue is the optimal means by which the clinician/learner is given access to an array of information resources along with powerful tools and interfaces for searching and browsing them. In this spirit, this study explores the effects of information retrieved from a computer-based resource on an individual's ability to solve problems in a relevant biomedical domain and compares the efficacy of Boolean and hypertext formats for accessing this information. The study was conducted in a laboratory setting in which these issues could be explored experimentally. The components of this setting include INQUIRER,[3] a full-text database in bacteriology providing both Boolean and hypertext access to the same corpus of information, as well as a set of case problems addressing the same biomedical domain. Because the key outcome measure in this study is the subjects' problem solving, the study falls under the category of "outcomes based evaluation" of information retrieval systems advocated by Hersh .[4]

STUDY QUESTIONS

This study addresses the following questions:

1) To what extent does information retrieved from a database help students solve problems in bacteriology?
2) Does this effect vary as students' levels of personal domain knowledge increase?
3) Is Boolean or hypertext access to a database more effective in supporting problem solving?

BACKGROUND

An emerging literature speaks to several of the issues explored in this study. Results from evaluations of systems designed for curricular support indicate that database use does have educational benefits. Hersh [5] compared the effects of Boolean-searchable and natural language-oriented versions of MEDLINE on the question-answering performance of medical students. Both systems supported the students in identifying literature that was helpful for this purpose. Of particular relevance to the current study are the results from earlier studies of INQUIRER, a factual database supporting the medical curriculum.[4,6-7] Results from these studies indicate that INQUIRER use was positively related to performance on course exams and students' ability to solve clinical problems. These studies demonstrate that databases in various forms are useful in improving student performance. Studies comparing online curricular support with printed versions of the same text have similar conclusions. For example, Egan and his colleagues[8] found that a

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searchable/browsable version of a statistics text was more effective in helping students complete assignments than a print version of the same text.

Two prior studies have examined the effects of differences in personal domain knowledge on the outcomes of searching, i.e., on the searcher's *use* of the information retrieved. In one study of use of a hypertext database, both subject specialists and search specialists were more successful in answering questions than students.[9] In the other study, incorporating four assessment occasions spread over two years and three biomedical domains, useful retrieval of information from INQUIRER always augmented medical students' personal knowledge. In the bacteriology domain, in which three assessments were conducted, personal knowledge increased after course exposure then decreased six months later; database-assisted performance in solving clinical problems increased linearly over all three assessments.[6]

Additional studies have examined the effect of personal domain knowledge on various aspects of retrieval effectiveness, usually operationalized in terms of recall, and the process of searching. Results from studies of retrieval effectiveness are mixed, with some studies finding a relationship between the searcher's personal knowledge and recall[10-11] and other studies finding no relationship.[7,12-13] Three articles have reported research on the relationship between the searcher's domain knowledge and the process of searching. In these studies, level of domain expertise was related to the amount of off-line preparation for the search,[14] search strategy formulation,[14-15] use of hypertext links and the types of records selected for further examination,[16] and other factors. However, because of the small sample size in each of these studies, the researchers noted as many individual differences as differences based on level of domain expertise.

Some studies comparing hypertext use with more traditional information retrieval systems have been completed, but it is difficult to compare or integrate their findings because each database/system had slightly different features. When hierarchical menus (sometimes with auxiliary browsing capabilities) were contrasted with other search strategies, they were more successful than an index,[17] less successful than a printed version of the text,[18] and just as successful as a Boolean-searchable form of a comparable database.[12] When use of an index was compared with embedded hypertext links, the index users were more successful than the hypertext users on only two of six questions assigned; there was no difference in performance on the other questions.[19]

METHODS

Overview

To address the study questions, subjects were recruited and randomized to one of two modes of information access (Boolean vs. hypertext) to the same corpus of biomedical information. Each subject completed two assessments: the first before a course in bacteriology when personal knowledge was low and a second after the course when personal knowledge was higher. At each assessment, each subject completed eight case problems in bacteriology: first without and then with access to the INQUIRER database. The study questions were addressed by exploring whether subjects' performance on the problems was improved through information retrieved from INQUIRER, whether the extent of improvement was greater at the first or second assessments, and whether the improvement was greater for those subjects using Boolean or those using the hypertext access modes.

Subjects

Subjects were 42 first year medical students at the University of North Carolina recruited from a random sample of the class. Students with a graduate degree in any biomedical science or with an undergraduate major in microbiology were excluded from the study.

Information Resource

The INQUIRER database [5-7], as used in this study, consisted of two files: a "concepts" file with detailed explications of 33 central ideas of bacteriology (e.g. gene regulation, growth kinetics, toxin action) and an "organisms" file providing 35 fields of information about 65 medically important bacteria. The fields of the organisms file spanned organism characteristics and identification, colonization, mechanisms of infection, signs and symptoms of disease, disease prevention, and therapy. In the Boolean access mode, subjects accessed information by entering up to five keywords joined by Boolean AND and OR operations, or by requesting a display of all the information about a specific organism or concept. In the hypertext access mode, students selected one of seven entry points into the information and then specified a single-term search to identify an initial set of records. From there they could navigate the database by selecting hot text that linked them to related ideas, often navigating between the concepts and organisms files. The hypertext access mode of INQUIRER, as employed in the study, contained approximately 3600 such links.

Case Problems

The investigators developed 16 clinical case problems. Each problem involved a disease for which the etiologic agent was in INQUIRER. Each

problem included a case description and three questions: one asking the subject to list a set of possible infectious agents for the case, one asking for the most likely infectious agent, and one addressing an important basic science concept related to the case. The 16 problems were randomly divided into two sets, denoted Set A and Set B, after stratifying for family of infectious agents.

Procedure

Each subject participated in two assessments: the first occurring in November of 1994 prior to the course in bacteriology and a second in March of 1995 following the course in bacteriology. Each subject was randomized to the Boolean or hypertext group. Each group was further randomized into a sub-group that would complete case problem Set A at the first assessment and another that would complete Set B at the first assessment. Prior to the first assessment, each subject attended a 60 minute training session on INQUIRER which included work on practice problems similar to the clinical cases used in the assessments. At each assessment, subjects began by working all eight problems in their assigned set using their personal knowledge only. After handing in their answer sheets, they were asked to rework the same set of problems with assistance from the assigned version of INQUIRER. Subjects who completed case Set A at the first assessment completed case Set B at the second assessment, and vice versa, so all problems were novel to the students. The investigators scored all assessments from a predetermined key. Maximum score was six points for each question, 18 points for each case, and 144 points for each case problem set.

Independent Variables

This design has three independent variables: access mode (hypertext vs. Boolean: between subjects), problem set assignment (Set A or B at the first assessment: between subjects), and occasion of assessment (first or second: within subjects).

Dependent Variables

The dependent variables, computed for each assessment, were improvement scores: the difference between the score on the initial attempt at the case set and the score on the second attempt conducted with database assistance. The improvement scores were thus a measure of the benefit of the information gained from INQUIRER. We computed an overall improvement score, based on all questions in each case, as well as separate improvement scores for each question type: possible agents, most likely agent, and basic science.

Analysis

Separate analyses were performed using overall improvement scores and the improvement scores for each question type as the dependent variables. To explore whether information retrieved from INQUIRER was beneficial overall, we planned to employ a t-test against the hypothesis that improvement scores were greater than zero. However, the magnitude of the improvement scores was such that no inferential tests were necessary. To explore whether the benefit of information retrieved from INQUIRER depended on the extent of subjects' personal knowledge, we employed repeated measures ANOVA with specific attention to the main effect for occasion of assessment. To explore the differential effects of information access mode, the same repeated measures ANOVA was used with specific attention to the main effect for access mode.

RESULTS

Figures 1 through 4 portray the results for each analysis. In each figure, the mean improvement score is plotted as the vertical axis. Over all question types (Figure 1) for all subjects, the mean improvement score (± SEM) was 51.7 (± 2.9) for the first assessment and 32.0 (±2.3) for the second assessment. As the means are many times the SEM, they are significantly greater than zero. By repeated measures ANOVA, the main effect for assessment occasion was significant ($F(1,38) = 29.6$; $p<.0001$), suggesting that the utility of INQUIRER was greater for the low knowledge condition.

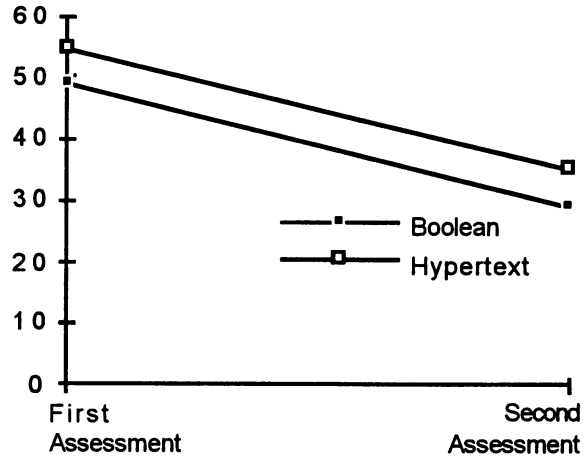

Figure 1- Results for Total Improvement Score

Even though there was a trend toward greater improvement scores for the hypertext version in comparison with the Boolean, the main effect for access mode falls short of statistical significance ($F(1,38) = 3.07$; $p=.08$).

For the "possible agent" questions (Figure 2), the mean improvement score was 16.4 (±1.1) for the first assessment and 5.4 (±.9) for the second assessment, again significantly greater than zero without need for inferential test. By repeated measures ANOVA, the main effect for assessment occasion was significant ($F(1,38) = 70.7$; $p<.0001$), suggesting again that the value of INQUIRER was greater for the low knowledge condition. For this question, the main effect for access mode was significant ($F(1,38) = 6.9$; $p<.02$), and favored hypertext.

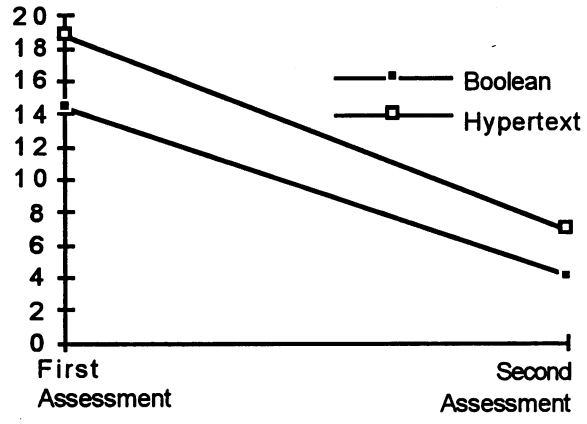

Figure 2 - Results for "Possible Agent" Questions

For the "most likely agent" questions (Figure 3), the mean improvement score was 25.5 (±1.5) for the first assessment and 18.6 (±1.7) for the second assessment, significantly greater than zero without need for inferential test.

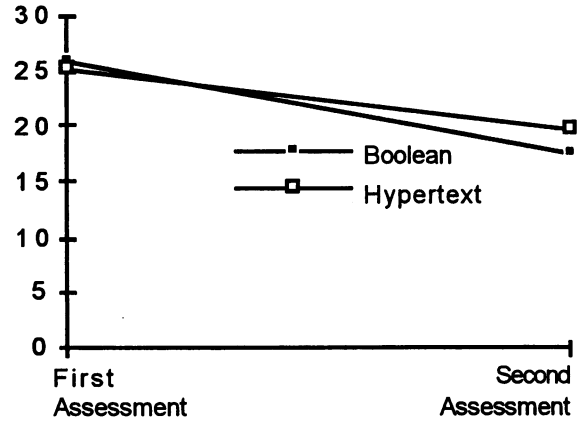

Figure 3 - Results for "Most Likely Agent" Questions

By repeated measures ANOVA, the main effect for assessment occasion was significant ($F(1,38) = 9.09$; $p<.005$), suggesting again that the value of INQUIRER was greater for the low knowledge condition. By repeated measures ANOVA, the main effect for access mode was not significant ($F(1,38) = .196$; $p =. 6$).

Finally, for the basic science questions (Figure 4), the mean improvement score was 9.7 (±1.3) for the first assessment and 8.0 (±.9) for the second assessment, significantly greater than zero. The main effect for assessment occasion was not significant ($F(1,38) = 1.91$; $p = .17$), nor was the main effect for access mode ($F(1,38) = .82$; $p = .37$).

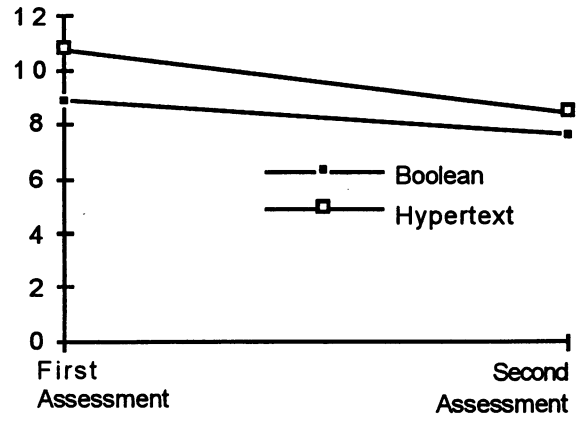

Figure 4 - Results for "Basic Science" Questions

DISCUSSION

Results of this study support findings from previous research that students, even when their personal knowledge is low, can retrieve information helpful to solving problems in a biomedical domain. For all assessments and all outcome measures, the improvement scores were substantial. The tendency for database information to be more helpful when personal knowledge is low is intuitively plausible because there likely exists a body of problem-relevant information which is both readily accessible in INQUIRER and also routinely learned by most students in their bacteriology course. At the first assessment, the students do not know this information but can obtain it from INQUIRER. By the second assessment, they have learned this material and are less dependent on INQUIRER, but the database is still helpful at this point.

The prominent independent variable in this study is the hypertext vs. Boolean access mode. The findings tilt toward greater utility for hypertext, but not decisively so. Subjects in the study were able to use both access modes to retrieve information that helped them in problem-solving. The difference between access modes was seen primarily in the "possible agent" questions. This may be a function of hypertext links built into INQUIRER which allow students who have found an organism that is a

possible cause of the disease in a case to link readily to other bacteria which have similar characteristics. Hypertext may also encourage and reward persistence in a way that Boolean searching does not. In a Boolean system, a student may conclude prematurely that the system has no useful information to offer if the initial search specification reveals no promising "hits." By contrast, the hypertext version guarantees immersion into the database information and the preformed links encourage additional exploration, allowing students to unearth relevant information whose existence was not quickly apparent.

The improvement scores in this study are probably somewhat inflated from their true levels by the so-called "second look" effect. On their second attempt at each problem, the students have additional time to think about the problem, to jog their memories and perhaps recall some additional relevant personal knowledge. For purposes of comparing the information access modes, however, this second look effect would operate equally on the two groups and thus not constitute a bias.

Further studies using the same experimental design are underway. These results may confirm, through a larger sample size, the benefits of hypertext access suggested by this work. These further studies are also examining the time to complete the exercise. While the browsing encouraged by hypertext may lead to greater retrieval of problem-relevant information, this may come at a substantial cost in time and efficiency.

Acknowledgments

This study was supported by Grant R01-LM04843 from the National Library of Medicine.

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